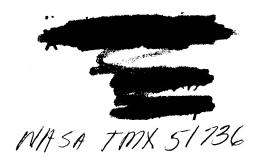
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### COMMUNICATION



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## SEMICLASSICAL CALCULATION OF INELASTIC CROSS SECTIONS FOR ELECTRON-CESIUM ATOMIC COLLISIONS

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The role of inelastic electron-cesium atomic collisions in thermionic diodes has recently received considerable attention. 1,2 Rizzo and Bell document the existence of excited 6P states of cesium in a plasma diode operating in the arc mode. Furthermore, stepwise ionization has been considered as an important source of ions in thermionic diodes.

The theory of Gryzinski<sup>5</sup> is utilized throughout this note to obtain semiclassical inelastic cross sections Q for various inelastic processes as a function of incident electron energy  $E_2$ .

The cross section for the collision of an electron with an alkali atom which will excite the atom's outer electron by an energy greater than U is given by Gryzinski as

$$Q(E_{Z}) = \frac{\sigma_{O}}{U^{Z}} g\left(\frac{E_{Z}}{U}, \frac{E_{1}}{U}\right)$$
 (1)

where  $\sigma_0 = 653 \text{ Å}^2$  -  $(\text{ev})^2$ ;  $E_1$  is the kinetic energy of the bound electron;  $E_2$  is the incident electron energy; and

$$g\left(\frac{E_{2}}{U}, \frac{E_{1}}{U}\right) = \left(\frac{E_{2}}{E_{1} + E_{2}}\right)^{3/2} \begin{cases} \frac{2}{3} \frac{E_{1}}{E_{2}} + \frac{U}{E_{2}} \left(1 - \frac{E_{1}}{E_{2}}\right) - \left(\frac{U}{E_{2}}\right)^{2} \\ \frac{2}{3} \left[\frac{E_{1}}{E_{2}} + \frac{U}{E_{2}} \left(1 - \frac{E_{1}}{E_{2}}\right) - \left(\frac{U}{E_{2}}\right)^{2} \right] \left[\left(1 + \frac{U}{E_{1}}\right) \left(1 - \frac{U}{E_{2}}\right)^{1/2} \\ \text{if } U + E_{1} \ge E_{2} \end{cases}$$

$$(2)$$

Hence the simple ground state ionization cross section is

$$Q_{i}(E_{2}) = \frac{\sigma_{0}}{U_{i}^{2}} g\left(\frac{E_{2}}{U_{i}}, 1\right)$$
(3)

where  $U_i$  is the ionization potential and  $E_1 = U_i$ .

Fig. 1 illustrates the agreement of Gryzinski's theory with experimental relative (normalized to the peak) values of the simple ionization cross sections for the alkali metals.<sup>6,7</sup> However, there does not appear to be sufficient data available to draw any conclusions about Gryzinski's prediction of absolute values of the simple ionization cross sections (Fig. 2). The ability of the theory to predict relative and absolute values of sodium excitation cross sections has been previously demonstrated.<sup>5</sup>

The electron-induced 6S to 6P cesium excitation cross section presented in Fig. 3 is given by

$$Q_{6S-6P}(E_2) = \frac{\sigma_0}{U_{6P}^2} g\left(\frac{E_2}{U_{6P}}, \frac{U_{1}}{U_{6P}}\right) - \frac{\sigma_0}{U_{5D}^2} g\left(\frac{E_2}{U_{5D}}, \frac{U_{1}}{U_{5D}}\right)$$
(4)

where  $U_{6P}$  is the lowest of the two 6P energy levels above the ground state (1.39 ev.<sup>9</sup>),  $U_{5D}$  is the lowest 5D level above the ground state (1.80 ev.), and  $U_{i}$  is the cesium ionization potential (3.89 ev.).

The total excitation cross section  $Q_{\mathbf{X}}$  is also presented in Fig. 3. It is the sum of all electron-induced excitations in cesium below the ionization potential. The result of this summation can be expressed as

$$Q_{\mathbf{X}}(\mathbf{E}_{2}) = \frac{\sigma_{0}}{U_{6P}^{2}} g\left(\frac{\mathbf{E}_{2}}{U_{6P}}, \frac{U_{1}}{U_{6P}}\right) - \frac{\sigma_{0}}{U_{1}^{2}} g\left(\frac{\mathbf{E}_{2}}{U_{1}}, 1\right)$$
(5)

where  $U_{6P}$  is the lowest 6P state. Nolan and Phelps<sup>1O</sup> experimentally obtained a peak value of  $50\text{Å}^2$  for the total cesium excitation cross section.

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It is noted that Gryzinski's theory gives better agreement (70Å<sup>2</sup> peak) with this experimental value than did previous analyses.<sup>11</sup>

Another interaction of possible interest in analyzing plasma diode performance is the electron-induced ionization of cesium in the 6P excited state. This cross section is given by

$$Q_{6P-i}(E_2) = \frac{\sigma_0}{(U_i - U_{6P})^2} g\left(\frac{E_2}{U_i - U_{6P}}, 1\right)$$
(6)

and is shown in Fig. 4.

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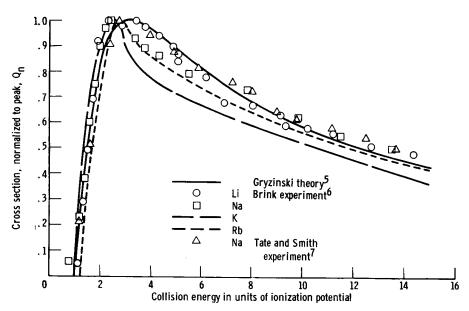


Fig. 1. Universal ionization cross section from classical theory.

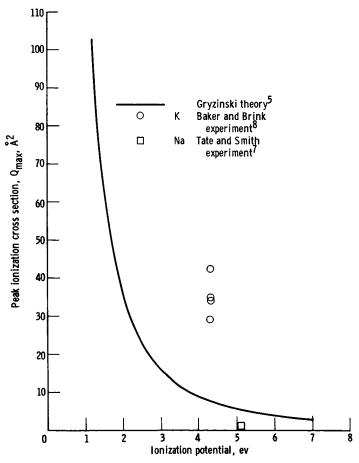


Fig. 2. Absolute value of ionization cross section peak.

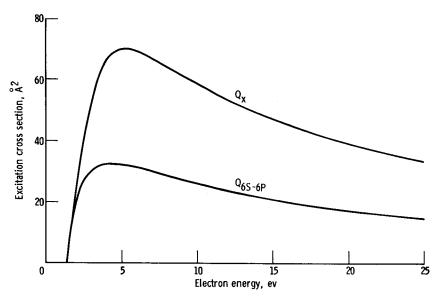


Fig. 3. Electron-induced cesium excitation cross sections.

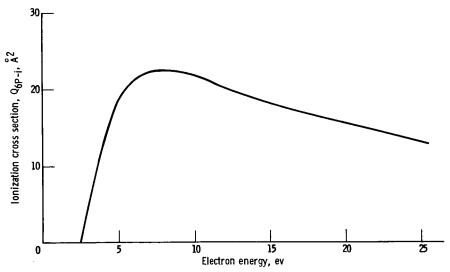


Fig. 4. Electron-induced ionization of excited (6P) cesium atoms.